Chapter 10
Air Sparging/Oxygen Enhancement With Air Sparging

10-1. General.

The process of air sparging, its applications, and effectiveness are described in the chapter's first section. The second portion of the chapter is a hazard analysis with controls and control points listed.

10-2. Technology Description.

a. Air Sparging Methods.

Groundwater air sparging involves the injection of air into groundwater to achieve the following objectives:

- Increased oxygen supply to promote aerobic biodegradation of certain contaminants.
- Removal of volatile organic compounds (VOCs) by physical mechanisms (e.g., desorption and volatilization of compounds directly into the enhanced air stream).

A typical air sparging system consists of specially designed injection wells to inject air into the formation, typically accompanied by a properly designed soil vapor extraction (SVE) system to capture the contaminated off gas. Air is injected into the subsurface under pressure, where it creates an inverted cone of partially aerated soils surrounding the injection point well. The air displaces pore water, volatilizes organics, and exits the saturated zone into the vadose zone. Off gas is then captured by an SVE system installed in the unsaturated zone and treated prior to release. The sparged air also transfers dissolved oxygen into the groundwater, capillary fringe water, and soil moisture in the unsaturated zone.

Nutrients can be injected into the unsaturated zone in water or injected into the saturated zone, dissolved in water slugs, and moved through sparging points or secondary injection wells. Indigenous microbes use injected oxygen and nutrients in enzyme reactions resulting in the transformation and/or destruction of the contaminants. A schematic diagram of an air sparging system is presented in Figure 10-1.

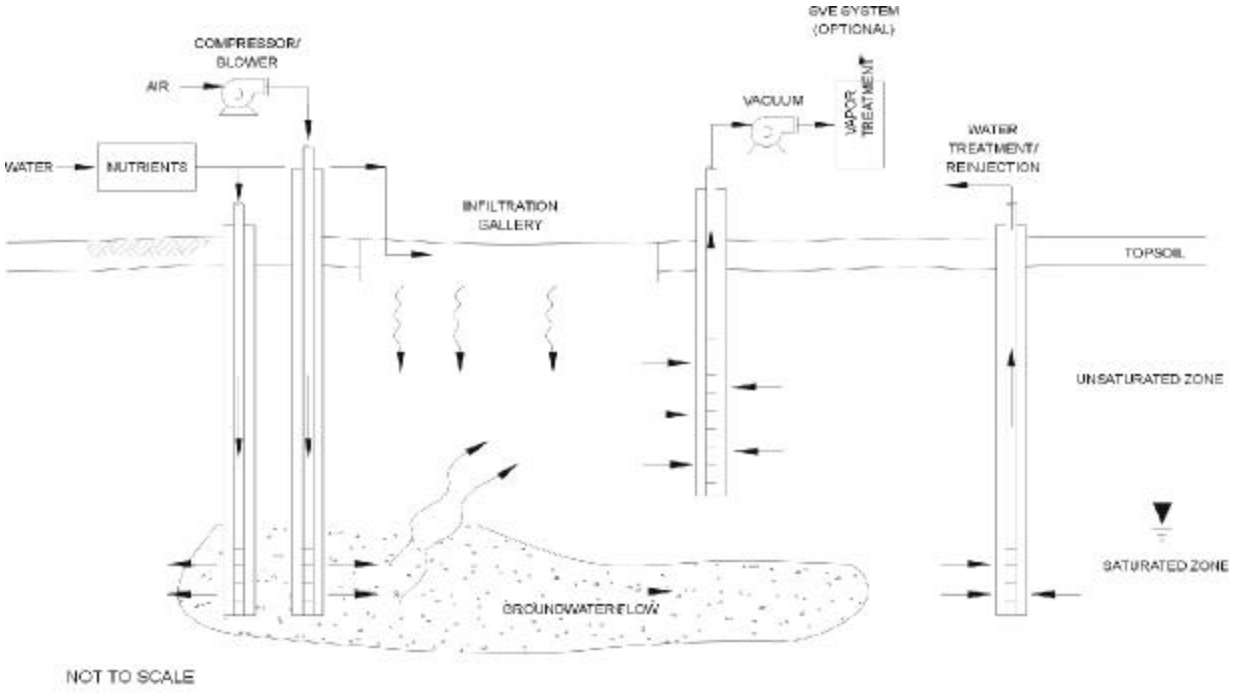

FIGURE 10-1. AIR SPARGING/BIOSPARGING

b. Applications.

Air sparging is effective for removing substantial quantities of volatile hydrocarbons and chlorinated organics in certain geologic settings. Air sparging can be enhanced by the use of oxygen, hydrogen peroxide, or ozone. Oxygen enhancement by the injected air can increase the oxygen content of the groundwater and soil gas, thus aiding bioremediation processes. Additions of ozone in sparging treatments can partially oxidize hard-to-treat organic compounds, such as chlorinated ethylene and complex aromatics, enhancing more traditional treatments by aerobic bioremediation and volatilization.

c. Effectiveness.

The effectiveness of air sparging depends on the geologic characteristics of the site, especially the ease of transmission of air through the soil pore structure. Groundwater air sparging occasionally requires groundwater pump-and-treat systems as well, since sparging effectively creates groundwater mounding around the sparge points, causing radial flow away from the points, and thus the potential to spread groundwater contamination.

10-3. Hazard Analysis.

Principal unique hazards associated with air sparging/oxygen enhancement, methods for control, and control points are described below.

a. Physical Hazards.

(1) Fire and Explosion Hazards (Drilling).
Description: Soil boring using hollow-stemmed augers may cause a fire or explosion during drilling into soils saturated with flammable or combustible materials in unusual or extraordinary conditions. Sparks generated when a metal auger bit strikes against rocks, metal, or other underground objects may ignite a flammable atmosphere inside the bore hole.

Fire or explosion may also result from drilling into soil contaminated with readily flammable/combustible wastes such as carbon disulfide, gasoline, or explosives such as metal fulminates. This hazard is rare.

Control: Controls for fire/explosion hazards include
- Use mud or water rotary drilling methods, which add moisture to the cutting area.
- Fill bore holes to prevent vapor accumulation.
- Have adequate fire fighting equipment always at hand to extinguish any fires generated.
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- CONTROL POINT: Construction, Maintenance

(2) Utility Contact Hazard.
Description: Fire, explosion, or electrocution hazards may exist when using hollow-stemmed auger drilling methods if the rotating auger contacts and/or ruptures underground utilities such as electrical and gas lines or contacts overhead electric lines.

Control: Controls for utility contact hazards include
- Contact local utilities and public works personnel to determine the locations of all utilities. When there is any doubt or uncertainty, conduct a utility survey, probe with a metal rod prior to excavation, or hand excavate to determine the exact location of utilities prior to drilling. Once utilities are located, careful excavation by backhoe may be allowed.
- Post an observer to the side to guide when raising a drill mast.
- Do not move the drilling rig with the mast raised.

CONTROL POINT: Design, Construction, Maintenance

(3) Fire (Oxygen Enhancement).

Description: Due to the presence of high levels of oxygen in an enhanced air sparge system, there may be an increased risk of starting a fire.

Control: A control for fire due to oxygen enhancement includes
- Inspect oxygen delivery systems regularly for leaks and the elimination of all sources of ignition.

CONTROL POINT: Operations, Maintenance

(4) Fire and Explosion (Flammable Gas).
Description: Fires and explosions may occur due to emissions of flammable VOCs at the surface or in the SVE collection system. Sparks, heat sources, and static electricity may ignite explosive gases, causing rupture of the collection system.

Control: Controls for fire/explosion due to flammable gas include
- Verify that the hazardous area classifications, as defined in NFPA 70-500 1 through 500-10, are indicated on the drawings.
- Use all controls, wiring, and equipment in gas collection that complies with EM 385-1-1, Section 11.G and NFPA 70 for the identified hazard areas.
- Use grounded equipment and/or equipment with ground fault interrupter circuit (GFIC) protection if required by EM 385-1-1, Section 11 or NFPA 70 requirements.
- Allow only trained, experienced workers to work on the systems.
- Inspect systems regularly for leaks.
- Control all sources of ignition.
- Ventilate areas adequately to help prevent the accumulation of flammable gases.

CONTROL POINT: Design, Construction, Operations, Maintenance

(5) Equipment Hazards (Drilling).
Description: The rotating drilling auger poses a hazard to workers as loose clothing may become entangled with the revolving auger.

Control: Controls for equipment hazards during drilling include
- Prohibit the use of loose clothing.
- Use low-profile auger pins.
- Use long-handled shovels to remove soil cuttings from the borehole.

CONTROL POINT: Construction, Maintenance

(6) Blower Hazards.
Description: Blowers may be equipped with unguarded pulleys that may cause entanglement of loose clothing.

Control: Controls for blower hazards include

- Use guarded pulleys and guarded moving or rotating mechanical devices on blowers.
- Inform workers that guards must be in place for equipment operation.

CONTROL POINT: Design, Operations, Maintenance

(7) Fire Hazard (Piping Systems).
Description: Piping systems that become plugged may induce failure of the vacuum pump causing an electrical fire. Also pipes or joints may burst from excessive pressure.

Control: A control for fire due to piping systems includes

- Inspect and clean piping systems periodically to help prevent blockage from material buildup.

CONTROL POINT: Design, Operations, Maintenance

(8) Heat Stress.
Description: Workers may be exposed to elevated temperatures due to excessive heating of blowers and other process equipment. The exposure may induce heat stress.

Control: Controls for heat stress include

- Use the correctly sized blowers, motors, and other equipment to prevent overheating.
- Train workers vigorously in the signs and symptoms of heat stress.
- Use the Buddy System and provide easy access to water.

CONTROL POINT: Design, Operations, Maintenance

(9) Steam Pressure Washing.
Description: Steam pressure washing of equipment may expose workers to thermal or burn hazards, eye hazards due to flying projectiles dislodged during pressure washing, slip hazards from wet surfaces, and noise hazards.

Control: Controls for steam pressure washing include

- Use insulated gloves (e.g., silica fabric gloves).
- Wear safety goggles and hearing protection.
- Wear slip-resistant boots.
- Drain water away from the decontamination operation into a tank or pit.
- Drain walking surfaces and keep free of standing liquids or mud.

CONTROL POINT: Construction, Operations, Maintenance

(10) Muscle Injuries.

Description: Manual lifting of heavy objects may expose workers to back, arm, and shoulder injuries.

Control: Controls for muscle injuries include
- Do not require workers to lift heavy loads manually.
- Use proper lifting techniques including stretching, bending at the knees, and bringing the load close to the body prior to lifting (see EM 385-1-1, Section 14.A).
- Use mechanical lifting equipment to lift or to move loads.

CONTROL POINT: Design, Construction, Operations, Maintenance

(11) Predesign Field Activities.
Description: Predesign field activities associated with subsequent construction may include surveying, biological surveys, soil gas surveys, geophysical surveys, trenching, drilling, stockpiling, contaminant groundwater sampling, and other activities. Each of these field activities may expose the survey personnel to physical, chemical, radiological, and biological hazards.

Control: Controls for hazards resulting from predesign field activities include
- Prepare an activity hazard analysis for predesign field survey activities. EM 385-1-1, Section 1.A provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

CONTROL POINT: Design

b. Chemical Hazards.

(1) Toxic Ozone Exposure.
Description: The use of oxygen or ozone enhancement may create an increased flammability potential or toxic (ozone) exposure.

Control: Controls for toxic (ozone) exposure include
- Ventilate the affected area adequately.
- Inspect piping systems regularly for leaks.
- Monitor for ozone and train workers in ozone hazard recognition including odor identification.

CONTROL POINT: Design, Operations, Maintenance

(2) Contaminants (Well Installation).

Description: During well installation, workers may be exposed to contaminants, such as VOCs, dusts, and metals in soil and development water through the inhalation/ingestion/dermal contact routes.

Control: Controls for contaminants include

- Apply water or an amended water solution to the area during well installation to help control the generation of airborne dusts, particulates, and VOCs.
- Use respiratory protection including approved filter/cartridges such as HEPA (N100, R100, P100) filters for particulates, OV cartridges for vapors, or combination filter/cartridges for dual protection.
- Analyze work tasks and potential for chemical exposure to determine the correct PPE and/or respirator cartridge(s). The analysis should include a chemical profile on the waste materials to help ensure the equipment specified will be appropriate for the respective chemical hazard(s).

CONTROL POINT: Construction, Maintenance

(3) Chemical Materials and Byproducts (Operation).
Description: During operation of the system equipment, workers may be exposed to chemical materials, such as hydrogen sulfide, VOCs, carbon dioxide, and intermediate byproducts by the inhalation/ingestion/dermal contact exposure routes.

Control: Controls for chemical exposure include

- Use proper ventilation.
- Wear appropriate PPE (e.g., an air-purifying respirator with organic vapor cartridges; air-purifying respirators for H_2S exposure are for escape only).
- Check closed systems, such as SVE, routinely for leaks with PIDs, air samples, O_2 meters, leak detection fluids, explosive gas meters, or specific gas tests such as Draeger-type tubes. Repair leaks immediately.
- Use vent stack heights that are adequate to disperse off gas.
- Designers: anticipate byproducts and products and make certain that the technology for off-gas treatment (e.g., activated carbon, condensation, catalytic oxidation) is effective and safe.

CONTROL POINT: Design, Operations, Maintenance

(4) Ozone Exposure.
Description: Ozone exposure may occur via the inhalation/dermal contact exposure routes from leaks in equipment used to generate ozone. Ozone is an irritant to skin, eyes and mucous membrane systems.

Control: Controls for ozone exposure include

- Use closed delivery systems for the addition of ozone to help minimize worker exposure.
- Test the equipment used to generate ozone for leaks prior to use.
- Perform regular maintenance and leak tests according to the manufacturer's instructions.
- Train workers in ozone hazard recognition.

CONTROL POINT: Design, Operations, Maintenance

(5) Hydrogen Peroxide Exposure.
Description: During handling of hydrogen peroxide, workers may be exposed to liquid hydrogen peroxide via the inhalation/ingestion/dermal contact exposure routes. Hydrogen peroxide is an irritant to the skin, eyes, and mucous membranes.

Control: Controls for hydrogen peroxide exposure include
- Use closed delivery systems for the addition of hydrogen peroxide to help minimize worker exposure.
- Test the system for leaks prior to use.
- Perform regular maintenance and leak tests according to the manufacturer's instructions.
- Train workers in hydrogen peroxide hazard recognition.

CONTROL POINT: Design, Operations, Maintenance

(6) VOC Migration.
Description: Injection (sparging) wells may cause migration of VOCs into subsurface structures, such as basements and sewers. The VOCs may be toxic and/or flammable, resulting in chemical exposure or the potential for a fire or explosion.

Control: Controls for VOC migration include
- System designer: determine the pressure range of the system and install hazard warning alarms to prevent over-pressurization.
- Perform periodic air testing in basements and other areas where VOCs may migrate to ensure safe levels.

CONTROL POINT: Design, Operations, Maintenance

(7) Confined Space Chemical Hazards.
Description: During entry into confined space, such as a manhole to collect condensate samples, workers may be exposed to airborne chemical hazards if the atmosphere in the confined space contains a toxic chemical or is oxygen deficient.

Control: Controls for confined space chemical hazards include

- Implement a confined-space entry program that includes worker training and air-testing procedures prior to entering confined space (see 29 CFR 1910.146).
- Test all atmospheres of confined space prior to and during entry.
- Ventilate confined spaced if a hazardous atmosphere exists.

CONTROL POINT: Operations

(8) Toxic Intermediate Products.

Description: Biological degradation of certain chlorinated organic compounds may produce toxic intermediate products including vinyl chloride. Vinyl chloride exists as a gas and may accumulate to higher levels in boreholes or in the system. Workers may be exposed to intermediate products during operation or maintenance of the system.

Control: Controls for toxic intermediate products include

- Ventilate the affected area.
- Select the proper respirator according to 29 CFR 1910.1017 or 29 CFR 1910.134 for other intermediate products if exposures are not less than the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL).
- Check with the respirator manufacturer to verify use in atmospheres containing vinyl chloride.
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- CONTROL POINT: Design, Operations, Maintenance

c. Radiological Hazards.

Radon Exposure.

Description: In some geological settings, workers may be exposed to naturally occurring radon gas. The gas is drawn from the soil in the SVE stream. Radon gas and radon progeny do not present a significant external hazard. While breakdown products of radon (progeny) may present an inhalation/ingestion hazard, quantities of radon progeny normally present would not pose a significant exposure hazard.

Control: Controls for radon exposure include

- Check for proper operation of emission control technologies to limit exposure to acceptable levels.
- Consult a qualified health physicist if excessive levels are suspected or encountered.

CONTROL POINT: Design, Operations, Maintenance

d. Biological Hazards.

(1) Biological Contaminants.
Description: At those sites involving medical wastes or sewage sludge, microorganisms in the soil may pose exposure hazards during system installation activities. Workers may be exposed to inhalation/ingestion/dermal contact with pathogens such as *Coccidioides sp., Histoplasma sp.,* and *Mycobacterium sp.* if contaminated dusts become airborne.

Control: Controls for biological contaminants include
- Reduce the generation of airborne microbe-contaminated dust with the periodic application of water, surfactant amended water, or emission-suppressing foams to the active excavation/drilling areas. The addition of foam to control vapors may also create a slip and fall hazard. Workers should not walk on areas where foam has been applied.
- Erect wind screens and use portable surface covers.
- Use the proper types of PPE: an air-purifying respirator with HEPA (N100, R100, P100) filter/cartridge and rubber gloves.
- Use experienced workers, repeated health and safety meetings, decontamination stations, and other standard procedures.

CONTROL POINT: Construction, Maintenance

(2) Pests.
Description: Workers may be exposed to a wide array of biological hazards, including snakes, bees, wasps, ticks, hornets, and rodents during any phase of remediation. The symptoms of exposure vary from mild irritation to anaphylactic shock and death. Deer ticks may cause Lyme disease. Rodents can transmit Hanta virus.

Control: Controls for pests include
- Perform periodic inspections of the site to identify stinging insects and to check for snakes and rodents.
- Use professional exterminating companies if necessary.
- Use tick and insect repellents for exposure control. Workers should check their skin and clothing for ticks periodically.

CONTROL POINT: Construction, Operations, Maintenance